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Identification of oxygen-rich late/post-asymptotic giant branch stars and water fountains via maser and infrared criteria

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Abstract. The transitional phase between the asymptotic giant branch (AGB) and post-AGB phases holds the key to our understanding of the late-stage metamorphosis of intermediate-mass stars. In particular, high velocity jets forming during this phase are suggested to contribute significantly to the shaping of planetary nebulae. For oxygen-rich stars, the rare "water fountains (WFs)" have been regarded as representative objects in this phase, and it is important to identify more of them for further studies. Here we briefly report the results of our latest OH and H_2O maser surveys in which a new WF candidate (IRAS 19356+0754) was found. We also performed radiative transfer modelling on the spectral energy distributions (SEDs) of all known WFs. It is concluded that WFs might in fact not be the transitional objects, as opposed to previous belief. WFs could be AGB or post-AGB stars with no obvious similarities amongst their SEDs. Further efforts are still needed to improve the identification criteria.

1. Introduction

High velocity jets associated with asymptotic giant branch (AGB) and post-AGB stars could play an important role in the shaping of planetary nebulae. This process is often thought to mainly occur during the transitional phase between the AGB and post-AGB phases. In the case of oxygen-rich envelopes, the "water fountains (WFs)" — objects associated with bipolar jets traced by H_2O maser emission — have been suggested as possible representative objects for this short phase. Such objects are very rare, up to date there are only 16 confirmed members. In order to have a better understanding of the WFs, as well as their role during the late stages of stellar evolution, more samples are required. Hence, we explore better methods for identifying this particular type of AGB/post-AGB stars.

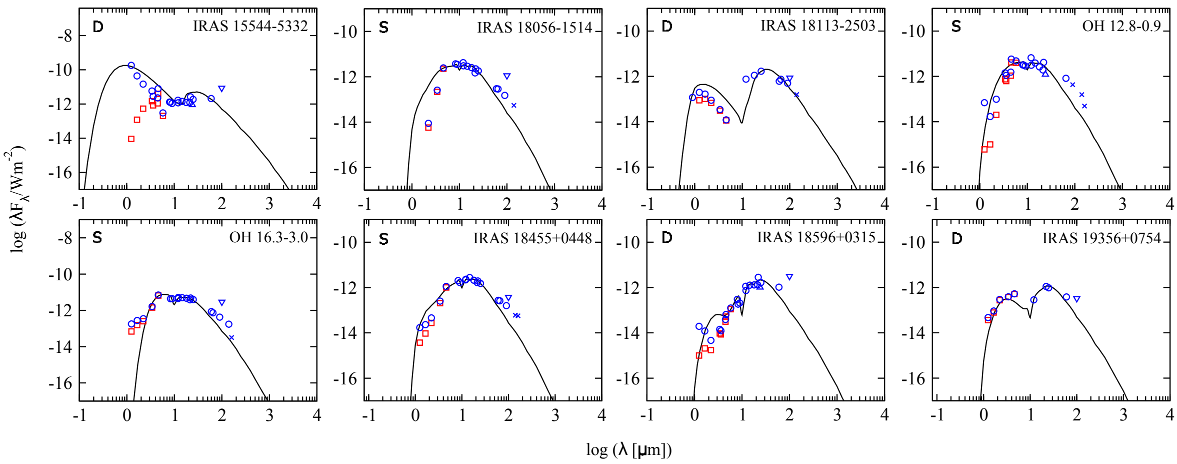

Figure 1. SEDs of WFs with the best fit DUSTY model curves. Only those with a good fit are shown here. "S" or "D" represent single-peaked or double-peaked profiles, respectively. Calibrated (○) and original (□, for $\lambda < 8$ μm) photometric data points are shown. Unreliable data points (×), upper (▽) and lower (△) intensity limits are also indicated, when applicable.

2. Maser survey and spectral energy distribution modelling

Our approach is to perform high sensitivity maser surveys, and to look for characteristics from the infrared spectral energy distributions (SEDs). We performed an OH and H_2O maser survey with the Effelsberg 100 m radio telescope in late 2012. The 1612, 1665, 1667 MHz OH maser lines and the 22 GHz H_2O maser line were observed with root-mean-square noise levels down to about 1–10 mJy. A total of 108 objects were covered (but not all of the objects were observed in all maser lines). A new WF candidate, IRAS 19356+0754, was identified. This object demonstrates large spectral velocity coverage in both the 1612 MHz OH ($\sim$67 km s^{-1}) and H_2O ($\sim$119 km s^{-1}) maser spectra, which is a clear sign of a high velocity outflow (see [1] for details).

We also constructed the SEDs of all known WFs from archival infrared photometric data. The SEDs were then modelled by the one-dimensional radiative transfer code DUSTY [2]. We found that WFs exhibit various types of SED profiles, and not all of them were well fit by the DUSTY models. Good fits could be obtained for eight WFs. Their SEDs and the corresponding best fit model curves are shown in Figure 1. Amongst these cases, four have a single-peaked SED profile resembling those from AGB stars, while the other four have a double-peaked profile and they are more likely post-AGB stars.

To conclude, WFs are difficult to be identified even with such a high sensitivity maser survey. We suggest that WFs are not necessarily the transitional objects between AGB and post-AGB phases, because no obvious common characteristics are found from their SEDs. However, if WFs could spread across various evolutionary phases, then it remains unclear why they are so rare.

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